A HYBRID ROCKET APPROACH TO SPACE EDUCATION

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ABSTRACT

In this paper, a hybrid student rocket payload is described as planned to become a part of Norwegian space education with the goal to teach and inspire the next generation of the space industry.

The hybrid rocket is a possibility for students to be involved in a rocket campaign where they take the role as launch crew, as well as scientists and engineers, to make the campaign a success. A new and improved encoder will enable more advanced student payloads than what is currently used in Norway. The hybrid technology will enable more hands-on activities than previously available.

A new technical development for the hybrid rocket payload will be the ability to launch CanSats over sea. The housekeeping system and structure is designed for this application in addition to the standard student sounding rocket campaign. The deployment of CanSats will be verified by telemetry, and will be done without explosives.

1. INTRODUCTION

In 2007 Nammo Raufoss made the first successful flight with a Norwegian built hybrid sounding rocket [1]. This was a great success, but unfortunately this rocket motor was too big for the Norwegian Centre for Space-related Education (NAROM) student rocket campaigns because of the campaigns short time span and limited budgets. But Nammo has proved that there is a demand in the launcher industry to such a new type of rocket motor, that they have gotten funding from the European Space Agency (ESA) for a pre-study to derive the usage for hybrid motors in their launch fleet. The first step is to start with a small prototype to prove that the rocket motor concept works. This is the history how this new Student Hybrid Rocket (SHR) came into life.

This paper discusses how the payload is composed, a brief description of subsystems for the salvo of test rockets. It also discusses how students will utilize this too as a launch vehicle for CanSats, and also how they will gain hands on experience with the combination of involvement of CanSat development and launch campaign.

The hybrid student rocket will be the first sounding rocket solely developed in Norway. Both the motor and payload will be made in Norway.

2. MOTOR

The motor is a new prototype hybrid rocket motor developed by Nammo Raufoss. It is based upon N_2O and HTPB. This motor is based upon the Hybrid Test Rocket launched in 2007 and described in [1]. The propellant and oxidizer are the same materials as used by SpaceDev in the SpaceShip One hybrid motor, and described as safe to handle compared to motors with explosives [2]. They state that the Vandenburg range rates the LOX / HTPB combination as 0lb of TNT equivalent.

3. PAYLOAD

The main purpose of this payload was originally to be a launch vehicle for transporting CanSats to about 10km altitude, were they will be dropped over ocean. But the payload can also be used to demonstrate technology under special circumstances.

The bigger payload section makes it possible to use bigger payloads, and also combine CanSats with other experiments.

The new payload will provide students with a considerably larger volume to fill with instruments. This will make instrument design and integration simpler, and instruments not previously flown on student rockets can now be tested.

The test flights will not contain any sort of CanSats or student developed electronics due to that it is only a technological demonstration to get statistics and flight heritage for the rocket motor.

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3.1. Structure

The structure is made from aluminum. Inside, the deck structure is partly similar to the 14 inch payload configuration [3], while one section is placed vertical to make room for larger PCBs. This enables the greatest possible number of applications and adaptability of the payload.

The nose cone is made with a Von Karman shape. This shape is mathematically derived to minimize drag at sub-sonic flights/speeds. This is the first payload which has a mathematically defined nosecone for optimal performance for sub-sonic flight.

The nose cone is given by its length, diameter and shape. We choose the length to be 4 times the payload diameter and the shape to be the Von Karman shape, which is given by equations 1 and 2 [4].

$$\theta(x) = \arccos\left(1 - \left(\frac{2x}{\mathrm{L}}\right)\right) \qquad (1)$$

$$r(x) = \frac{\mathrm{R_b}}{\sqrt{\pi}}\sqrt{x - \frac{\sin(2\theta)}{2}} \qquad (2)$$

Where:

$\mathrm{R_b}$: Nose outer base radius

x : axial position from the nose tip

r : radius as a function of x

θ : Profile angle

L : Nose length

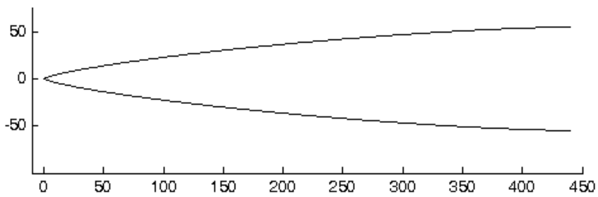

Figure 1, Von Karman shape nosecone, scale in mm

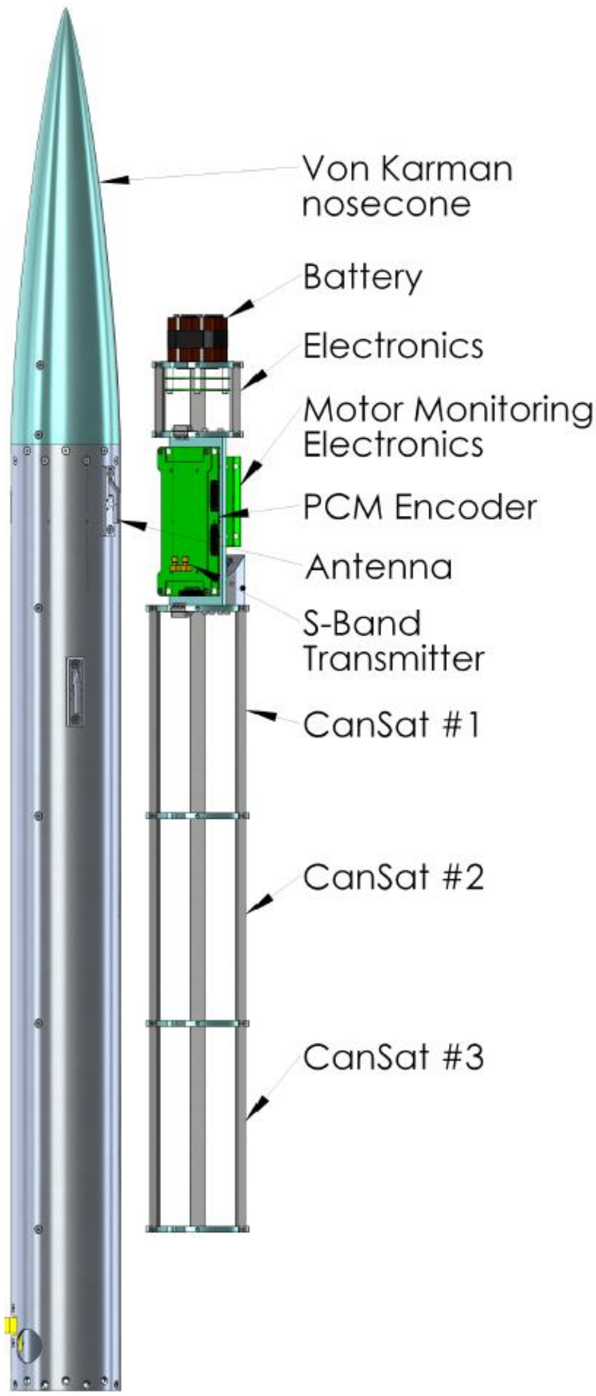

Figure 2, Payload Overview

3.2. Telemetry & Housekeeping

This student payload will feature all the functions that is required e.g. for a much complex payload like the 14 inch by ARR. It will contain timers for CanSat deployment, PCM encoder capability, transmitter, power control and monitoring of all the subsystems. The extra tasks for the qualification flights is monitoring of the rocket motor performance.

The electronics development for this project is based upon flight heritage from a numerous CRV-7 student rocket [5], and the MiniDusty concept [6] from the University of Tromsø.

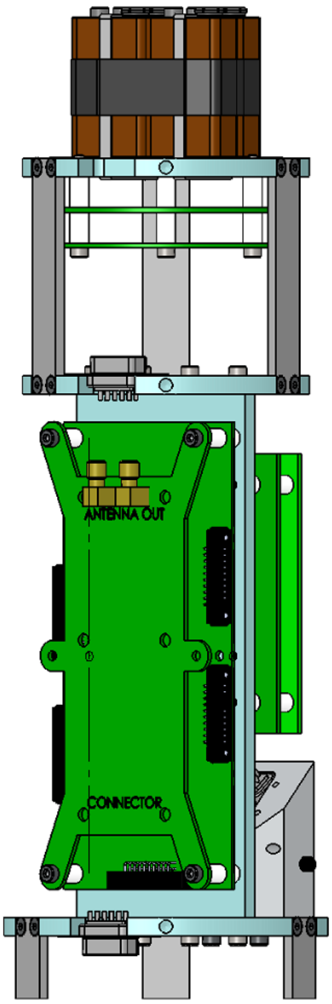

Figure 3, Batteries, electronic section and housekeeping

The housekeeping system consists of the encoder, attached to the EGSE with the umbilical connector, 4 batteries (9V) and an interface to the motor sensors. The encoder is developed at the University of Tromsø and based on a design previously used on the MiniDusty rocket program.

3.3. Instruments

The most important instruments in the qualification program will be the instruments measuring the motor performance, along with magnetometers and accelerometers.

There will also be a standard package derived from today's student rocket instruments, in order to qualify them for the new configuration as well.

An option to include an onboard video camera also exists, but this will be omitted.

Simulations show that it is feasible to use a low cost GPS receiver as additional means of determining the position of the rocket. As shown in figure 4, the rocket is inside the speed and acceleration limits of civilian GPS units after less than 10 seconds after launch [7]. This means that most of the flight can have GPS data in addition to the position data provided by the rocket range trajectory and positioning system.

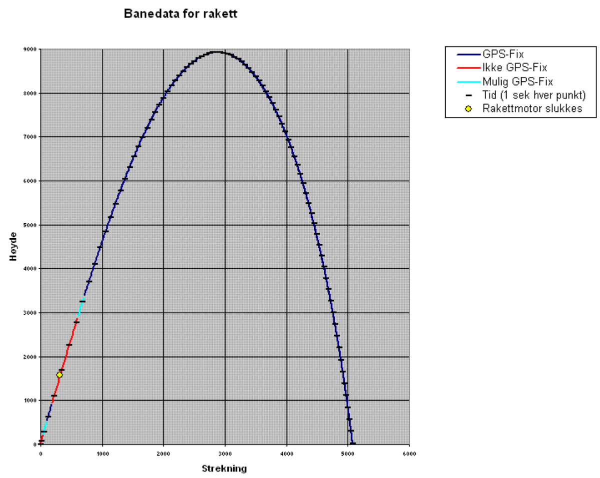

Figure 4, GPS lock vs trajectory simulation [7]

3.4. Ground support

The electronic ground support equipment (EGSE) will now be the same as for the 14 inch payload provided by ARR. This means that the hybrid rocket campaigns will be conducted similar to the more advanced rockets, were all the involved experimenters are kept outside the safety area, but still with full control over the payload. This will enhance the professionalism of the student rocket campaigns. There will also be a motor ground support system in place, to fill the fuel-tank, and monitor the motor before launch. This part will be more complicated than the traditional solid fuel sounding rockets [1].

4. Flight Qualification

All rockets launched from ARR must have been proved reliable, and been qualified. The qualification for this payload will be less excessive than for the solid rocket boosted payloads, since it will never experience super-sonic flight. But it will undergo bending, balancing and vibration tests in order to map the mechanical properties of the payload.

The test plan will be less extensive than the testing for the larger sounding rocket payloads, because this rocket will experience smaller loads and a shorter flight time. Tests that will be done include bending and vibration testing, as well as electronics testing.

5. STUDENT USE

Students will be able to build all sorts of instruments that can fit inside the payload. They will have much power at their disposal. For the students, this will be a more real rocket campaign experience than the current generation student rockets.

5.1. Student rocket campaign

At the start of the student rocket campaign, the students are divided into teams working on the different aspects of the campaign. The teams are usually the motor team, the telemetry team, the payload team and the instrument team. Occasionally there will be a science team as well.

The motor team will perform simulations on trajectory and motor performance, and will be manning the launch tower and the launcher crew.

Students in the telemetry team will learn about the telemetry systems and track satellites, and during the launch campaign, they will sit in the telemetry receiving data from the rocket.

The instrument team will build the scientific instruments that will fly, and during the launch they will work at the experimenters' desk, keeping an eye on the data from the rocket.

During the countdown they will need to confirm the status of these data and tell if they are satisfied with the status of their instruments.

The payload team also helps build instruments, and are responsible for the integration of the payload into the rocket. They are also responsible for spin testing the rocket as part of the student test program before launch.

The final team is the science team which will sit in the User Science Operations Centre (USOC) and report status of ground based and satellite measurements relevant for the launch campaign.

After the rocket has successfully transmitted measurements and plummeted into the sea, the students will be tasked with analyzing and explaining the data they have gathered, and look at how their pre-flight analysis of the conditions were correct or wrong.

5.2. CanSat

The rocket will be large enough to provide space for 3 regular size CanSats. A CanSat is a student built "satellite" in a soda can [8]. Such satellites are typically released from balloons or amateur rockets.

NAROM successfully conducted a CanSat pilot competition in May 2009, where several Norwegian high schools participated [9].

Figure 5, The inside of a CanSat kit used in the CanSat competition (R. Vanderberg, NAROM) [9]

The hybrid rocket can deploy the CanSats at the top of the trajectory. This will give them several minutes of fall time below a parachute on the way down, where they can act as drop-sondes before they land in the water. The hybrid rocket will be able to deploy the CanSats at an altitude of about 10 km.

Compared to the traditional land-based CanSat competitions, this will have a challenging twist, since the cans will land in the ocean. The cans will then need to be set up with beacons so the students can track them and pick them up. Also, they need to have some water-tight electronic section, as well as the ability to float and transmit. This concept will be radically different from any other CanSat competition that has been conducted so far.

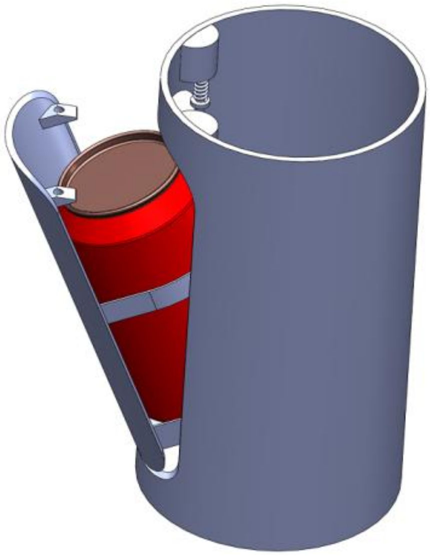

Figure 6, First Concept for releasing a CanSat [10]

A prototype CanSat release section is under development at the University of Agder, where a team of 3 students are working on this. The system involves opening a door in the payload and pushing the payload out. Depending on the loads experienced by the payload, a different solution might be necessary. The CanSat deployment mechanism will need to use one or more of the outputs from the encoder. As opposed to the most commonly used strategy in sounding rockets, the release will be done using no explosives to keep the handling of the rocket safe for students as well as to keep within the spirit of the motor without solid rocket fuel.

The greatest challenge with the CanSat deployment is to maintain the safety of the operation. Because the CanSat is fairly large compared to the payload diameter, the hole need to be quite large for the CanSat to go through. However, three large holes give us the challenge of maintaining structural integrity. Also, the speed where the CanSats will be deployed may cause them to violently hit the rocket fins or get damaged in other ways.

6. COMMISSIONING AND FUTURE PLANS

There will not be a significant student involvement in the qualification campaign for this rocket. When the rocket is put to use in student courses and campaigns, it is possible for students to participate in nearly all tasks. As before, the students can work on the instruments, payload, physics preparations and telemetry. In addition the students can support in attaching the payload to the motor, as well as installing the motor on the launcher, fuelling and monitoring it.

In order to make this rocket much used, the cost needs to be kept down. Since both the electronics and the structure are custom made, this is not an easy task. For future development of this, there will be a focus on making it simpler and less costly. Also, using solutions from this platform and spinning off into other areas are interesting concepts.

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